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ABSTRACT

This study was conducted to determine whether learner control of lesson strategy is superior to programmed control in computer-based instruction (CBI), and, if so, whether learner control is more effective when guidance is provided. Subjects were 164 trainees assigned to the Basic Electricity/Electronics School in San Diego. They were randomly assigned to three experimental treatment groups (unguided learner control, guided learner control and programmed control) and a control group. Lesson materials and objectives were the same for all groups; however, experimental groups used PLATO IV student terminals, while the control group used lesson booklets. Within-lesson performance of and lesson strategies used by the experimental groups were compared as well as the performance of the control and experimental groups on the post lesson performance tests and module examinations. Results indicate that learner control, with or without guidance, is not superior to programmed control as a CBI mode. However, the use of the learner control lesson structure may be desirable because of the possible economies to be effected. Also, since it appears that the rule-example-practice lesson strategy may prove to be optimum for all students, consideration may be given to delivering this strategy in an adaptive programmed control mode. A list of 17 references is provided. (Author/CHC)

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LEARNER CONTROL OF INSTRUCTIONAL SEQUENCE IN COMPUTER-BASED INSTRUCTION: A COMPARISON TO PROGRAMMED CONTROL

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FOREWORD

This research and development was performed under Z0108-PN (Education and Training Development), Subproject Z0108-PN30A (Adaptive Experimental Approach to Experimental Design). It was part of an Advanced Research Projects Agency/Joint Services Training Technology Program for the development of computer-based training technology.

Appreciation is expressed to the following:

- Personnel of the Basic Electricity/Electronics School, Service School Command, Naval Training Center, San Diego, who provided technical review of lesson content and furnished the students participating in this effort.

- Ms. Betty Whitehill of this Center, who was responsible for major portions of the computer coding.

Results of this effort are intended for use by the Chief of Naval Education and Training, the Chief of Naval Technical Training, and the Chief of Naval Education and Training Support (specifically the Instructional Program Development Centers). It is also directed at the educational research community.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

Although early research results indicated that learner control of lesson strategy might have significant pedagogical advantages, its utility has not been proven. Other research results suggest that study performance may be improved when guidance is provided. The question for research then is whether learner control would be effective in computer-based instruction (CBI) and whether such effectiveness could be improved by providing guidance.

Purpose

The objectives of this research were to determine whether learner control of lesson strategy is superior to programmed control in CBI, and, if so, whether learner control is more effective when guidance is provided.

Approach

Subjects were 164 trainees assigned to the Basic Electricity/Electronics (BE/E) School, San Diego. Subjects were randomly assigned to four groups: three experimental--unguided learner control (ULC), guided learner control (GLC), and programmed control (PC)--and a control (no CBI) group. Lesson materials and objectives were the same for all groups. However, materials for the experimental groups were presented via PLATO IV student terminals and those for the control group were provided by the lesson booklets (modules) normally used by the BE/E School. Within-lesson performance of and lesson strategies (e.g., rule-example-practice) used by the experimental groups were compared. Also, performance of the experimental groups and the control group on the post lesson performance tests and module examinations was compared.

Results

There were no significant differences in performance on the CBI tests among the experimental groups or on the module tests between the experimental and control groups. However, GLC students selected subject matter areas within a lesson in numerical sequence and used advisor strategies significantly more often than did ULC students. There were no significant differences in attitudes toward CBI among the experimental groups.

Conclusions

Results of this study indicate that learner control, with or without guidance, is not superior to programmed control as a CBI mode. However, the use of the learner control lesson structure may be desirable because of the possible economies to be effected. Also, since it appears that the rule-example-practice lesson strategy may prove to be optimum for all students, consideration may be given to delivering this strategy in an adaptive programmed control mode.

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Recommendations

It is recommended that this experiment be replicated, using other lesson materials and other subjects. Also, it is recommended that the question of whether there is an optimum lesson strategy be investigated by comparing various lesson strategies using a programmed control mode.

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INTRODUCTION

Background and Problem

The development of computer-based instruction (CBI) has progressed from linear programming, which presented the same instruction to all students, to multifaceted, adaptive programs, which give the student a variety of options and ways to influence and select his course of study. The extent to which the student can utilize his options and constructively influence his course of study has, in recent years, been the subject of considerable debate.

Although research results have generally supported the advantages of branching over fixed sequence programming (e.g., Hurlock, 1972; Slough, Ellis, & Lahey, 1972), the utility of learner control has not been proven. McCann, Lahey, and Hurlock (1973) concluded that learner control of lesson sequence may have only motivational advantages. Judd, O'Neil, and Spelt (1974) and Steinberg (1977) also found no clear mandate for the use of learner control.

The most persuasive literature on the subject of learner control is provided by Merrill and his associates (e.g., Merrill, 1973; Merrill & Boutwell, 1973). Merrill presumes that, given the opportunity to try a number of strategies, the student will in time arrive at an individually optimum strategy through his own learning process. More recently, Merrill (1975) has suggested that self-adaptation through learner control is more important to student success than adaptive programming based on aptitude-treatment interaction.

It appears to be logical to use some method other than the student's subjective assessment of his own understanding to control lesson strategy when it is available. Although Ausubel (1963), Bruner (1966), and Gagne' (1970) do not agree on the particular mechanics to be used, they all argue strongly for development, by instructional designers, of a hierarchical arrangement of lesson materials. Their theories suggest lesson structures having little or no room for student choice, although the course of study must be adaptive to student needs. Thus, their positions appear to be diametrically opposed to those of Merrill and his associates. However, it should be noted that the TICCIT (Time-Shared Interactive Computer-Controlled Information Television) System, which is used to implement the instructional system described by Merrill (1973), includes an elaborate advisor function to monitor and control the student's course of study. This function often prevents the student from advancing to succeeding lesson segments until he has mastered the content of hierarchically prior segments. Thus, the TICCIT System invokes significant bounds on the student's options--bounds that are compatible with the hierarchical theorems.

In an entirely different area, that of computer-managed instruction, it has also been argued that control of the student's course of study is necessary to the effective presentation of lesson materials. Anderson, Anderson, Dalgaard, Paden, Biddle, Surber, and Alessi (1975) have demonstrated the effectiveness of the Computer-Assisted Instruction Study

Management System (CAISMS), which directs students through a sequence of off-line study assignments followed by on-line quizzes. It has been shown that use of this system improves student performance. Between the positions of rigorous programmed control and learner control lie a variety of alternatives in both the computer-based and computer-managed instruction areas.

One of the likely outcomes of learner control is the occurrence of non-productive responses. Some students seem, on occasion, to completely lose their sense of purposeful direction or perspective. To prevent this from happening or to help a student to choose between equivalent alternatives, some instructor guidance would seem to be appropriate. The instructor who has labored over and has experience with his lesson materials during student tryouts can, at the very least, point to a "normative" path that has been useful to a majority of his students, while letting the student decide whether or not to follow that path.

Purpose

The purpose of the research project described herein was to evaluate the effectiveness of normative guidance of the instructional sequence. Further, since a simple comparison of guided and unguided study will not address the more basic question of whether learner control is in fact superior to programmed control, a third group was included in the experimental design. This group had no options, but went through the lessons under programmed control, studying the lesson segments and lesson content in an order preestablished by the lesson developers. This research project thus addressed these two questions:

1. Is learner control of lesson strategy superior to programmed control in computer-based instruction (CBI)?

2. If so, is learner control more effective when guidance is provided to the learner control student throughout his course of study?

Since learner control often means different things to different researchers (Judd et al., 1974), for purposes of this report, learner control is defined as the freedom to choose lesson segments and lesson content in any sequence. The lesson format is described in Lahey, Crawford, and Hurlock (1976).

METHOD

Subjects and Design

The subjects were trainees assigned to the Basic Electricity/Electronics (BE/E) School, Service School Command, Naval Training Center, San Diego. A total of 164 participated, 124 assigned to three experimental groups, and 40, to a control group. The three experimental groups were unguided learner control (ULC) (N = 38), guided learner control (GLC) (N = 44), and programmed control (PC) (N = 42). Students going through the BE/E School were selected randomly by learning supervisors as they reached the appropriate point in their studies. If space was available at a computer-based instruction (CBI) terminal at the time a student was selected, he was assigned to an experimental group (the specific group was determined using a random numbers table adjusted at the mid-point and ~~the end of~~ the selection period to roughly equalize the distribution). If space was not available at the time of student selection, he was assigned to the control group. The means and ranges for the General Classification Test and Arithmetic Reasoning Index scores obtained by students assigned to the four treatment groups were essentially the same, as is indicated in Table 1.

Table 1

General Classification Test (GCT) and Arithmetic Reasoning Index (ARI) Measures for Experimental and Control Groups

Group	GCT Mean	GCT Range	ARI Mean	ARI Range
Unguided Learner Control (N = 38)	61	46-68	58	45-69
Guided Learner Control (N = 44)	58	45-68	60	46-69
Programmed Control (N = 42)	59	39-68	59	36-69
Control (No CBI) (N = 40)	58	41-66	59	41-69

Training Materials

CBI

The CBI training materials consisted of an introductory lesson on how to use the computer terminal (PLATO IV) and four lessons that were required parts of the students' training. Three of the lessons taught students how to use the Simpson Model 260-5P multimeter as an ohmeter (Ohms Lesson), a DC ammeter (Amps Lesson), and a voltmeter (Volts Lesson) respectively. The other, which was presented third in the lesson sequence, was a lesson on voltage in series circuits. The contents of the Ohms, Amps, and Volts Lessons were structured compatibly to reduce irrelevant learning requirements. The four lessons were equivalent in content to the regular course materials used by the BE/E School.

The four CBI lessons were segmented by subject matter areas into lesson segments, each of which covered a training objective. There were 10 lesson segments in the Ohms Lesson, 9 in the Amps Lesson, 4 in the Voltage Lesson, and 10 in the Volts Lesson. When a student signed on to the computer to take a lesson, an index of the subject areas would be presented on the plasma-screen terminal, as is illustrated in Figure 1. When the student selected a lesson segment, the training objective for that area would appear on the screen, as is shown in Figure 2. Lesson materials (content) within each lesson segment consisted of rules, examples, and practice problems, at three levels of difficulty--easy, medium, and hard. Rules were generally text presentations. Examples and practice problems were generally graphic presentations, differing only as to their expository/inquisitory nature. Responses to practice problems were normally in a four- or five-part multiple-choice format, except for problems involving connecting the meter to simulated circuits and making readings, which required fill-in responses.

The learner control student accessed the desired lesson content (rules, examples, or practice problems) by touching the appropriate function block on the screen. His choice was then presented on the screen at the level of difficulty he had chosen--easy, medium, or hard (the default condition was usually the medium level). If the student needed help to understand or complete his selection, he might press the "help" block (see Figure 2), and explanatory material (either textual or graphic) would appear on the screen. When he had finished the particular subject matter area (i.e., by completing a requisite number of problems), he would press the index block to return to the lesson index.[1]

As shown in Figure 1, a diagram provided to the right of the index let the student check his progress within a lesson. For example, if a student had accessed but not completed Lesson Segment 4 (Connecting the Meter), the box identified by number 4 in the diagram would be double-lined; if he had completed it, the box would be cross-hatched as well.

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[1]This arrangement was used in previous studies conducted to investigate the feasibility of simulating the multimeter function (see Lahey, Crawford, & Hurlock, 1976).

SUBJECT MATTER AREAS: Ohmmeter lesson.

↓

1. Jack locations.
2. Deenergizing circuits.
3. Setting the function switch.
4. Connecting the meter.
5. Zeroing the ohmmeter.
6. Interpolating on the ohms scale.
7. Reading the ohms scale.
8. Setting the range switch.
9. Checking the circuits for shorts and opens.
10. Mini-lab.

t. ** Progress check **

SELECT a subject by number →

Press HELP for additional options.

Order of precedence:

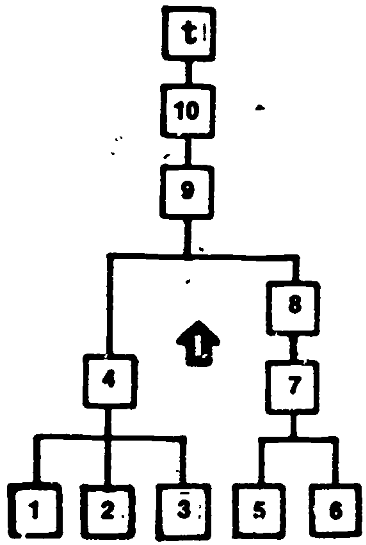

Figure 1. Lesson index: Ohms Lesson.

When measuring resistance, you'll need to find testpoints (tp's) to use which isolate the resistance you want to measure. The best way to see this is by example. Be sure to try several.

EXAMPLE	RULE	PRACTICE	Easy	Medium	Hard	Help	Index

Figure 2. Sample objective page: Ohms Lesson.

Control—

The control group studied the same four lessons, using the regular individualized lesson booklets (Modules 3 and 4) used by the BE/E School. These booklets feature short narratives and summaries and detailed frame-oriented programmed instruction sequences. Also, the control group had access to a number of training aids and to a laboratory where they were directed to conduct an experiment with the multimeter. The CBI groups did not have access to the training aids or to the laboratory.

Procedure

CBI Groups

All CBI groups were required to take the four lessons on the use of the multimeter in a fixed sequence (Ohms, Amps, Voltage, and Volts), and to attain a score of 78 percent or more on an on-line test on the content of one lesson before proceeding to the next. The ULC and GLC groups had complete freedom of choice in selecting (1) the subject matter area from the lesson index, (2) the type of lesson content (i.e., rule, example, or practice) within the area chosen; and (3) the level of difficulty (i.e., easy, medium, or hard).

After members of the GLC group had made an initial content selection, an advisor subroutine made recommendations for further selections, as is indicated in Figure 3. For example, suppose that a member of the GLC group was taking the Ohms Lesson and had selected Lesson Segment 4 (Connecting the Meter) from the index shown in Figure 1. The expanded training objective for this area would then appear on the screen, as shown in Figure 2. At this point, the student was free to choose the type of lesson content to be accessed and the level of difficulty. However, after he made his initial selection, the advisor subroutine, Figure 3, was used to recommend what to select next. If the student's initial choice were the RULE, the advisor would recommend that he perform an EXAMPLE; if the choice were an EXAMPLE, the advisor would recommend that he study the RULE. However, if the initial choice were PRACTICE, the advisor would make no recommendations until the practice problem was completed.

Although the PC group also studied each lesson in succession, they had no options within the lessons; that is, members had to study each subject matter area in numerical succession and to follow a prescribed rule-example-practice sequence of lesson content within each objective. For example, suppose that a member of the PC group was taking the Ohms Lesson (the first in the sequence). He would have to begin with Lesson Segment 1 (Jack Locations). After the expanded training objective for this area appeared on the screen, the PC student would see a RULE at the medium level of difficulty. He would then rigidly follow the sequence of steps indicated in Figure 3.

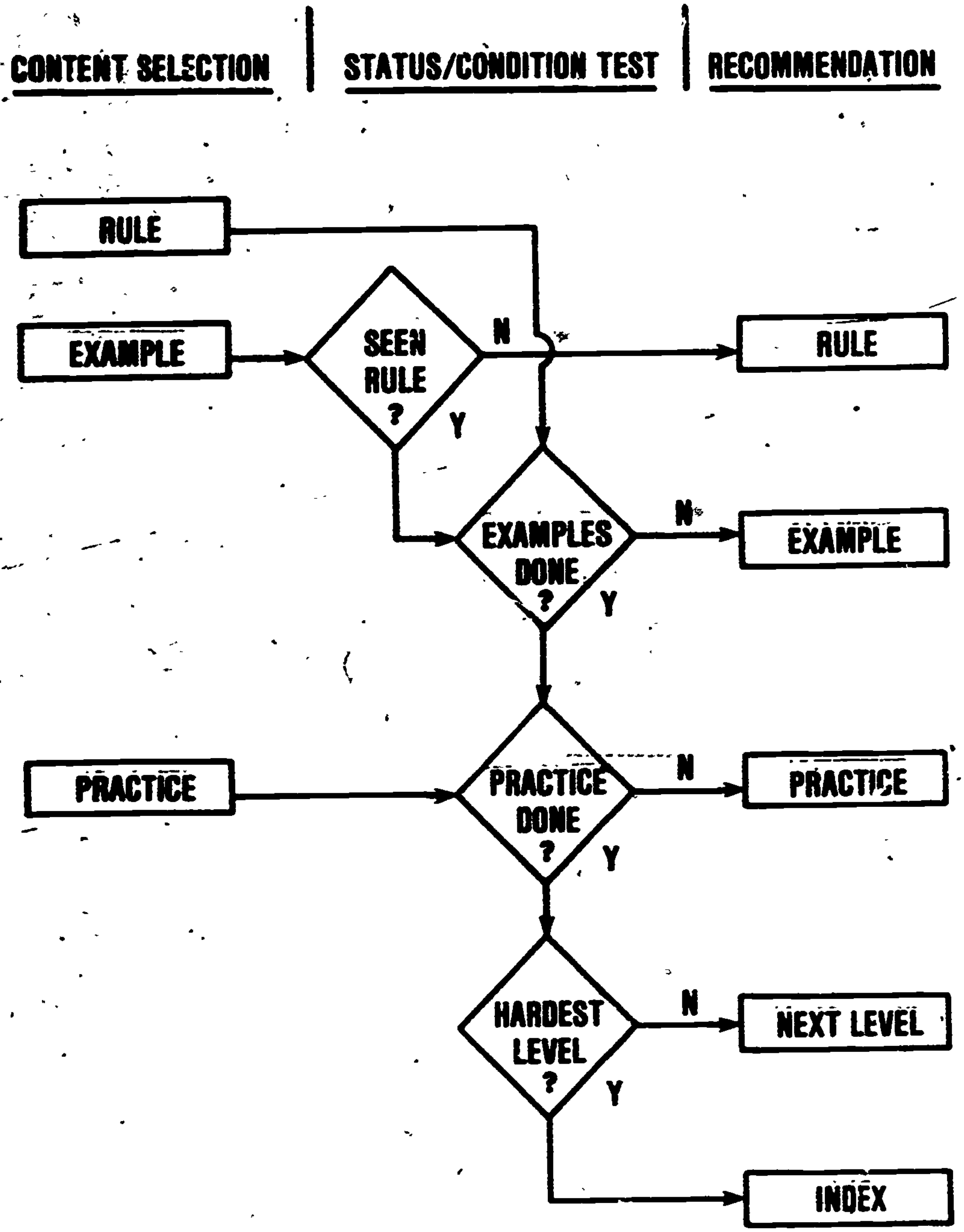

Figure 3. Advisor function.

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Students in all CBI groups were required to indicate how confident they were that their answers to practice problems were correct. If they were not sure of their response to a problem or admitted that they had "guessed," they had to do an additional practice problem before they were given credit for a completed problem.

Students who failed the on-line test on the content of any lesson were shifted to the ULC mode for review, allowing them to study as much or as little as they chose to before retaking the test.

After students in the CBI groups had completed the Ohms Lesson, they took a post lesson performance test and an examination on the entire content of Module 3 of the BEEINLES course. After they had completed the remaining three lessons, they took a post-lesson performance test and an examination on Module 4. Finally, CBI students completed a questionnaire on their attitude toward CBI instruction.

Control Group

After members of the control group had studied their lesson booklets and performed a laboratory experiment on the use of the multimeter, they took the same post lesson performance tests and examinations given the CBI students.

Content Selection

To test the null hypothesis that the treatments did not differ, it was necessary that the students in the ULC and GLC groups occasionally used strategies other than the rule-example-practice strategy used by the PC group. To identify the alternative strategies used, the number of possible sequences used were reduced to a manageable, identifiable set by establishing the following a priori rules:

1. A student's strategy was determined by the order in which he selected types of lesson content during his initial accession of a subject matter area. Repetition of a particular content selection or subsequent returns to the lesson segment after once leaving it were ignored.

2. The student's decision to take the criterion test terminated the strategy selection process. The strategy for those subject matter areas not accessed before taking the test was "omit."

3. A student's dominant strategy (used for a posteriori analysis) was that strategy selected in at least 40 percent of the 33 subject matter areas in the four lessons, and in at least 6 areas (60%) of the final lesson (Volts).

Experimental Measures

Detailed records of student performance were kept during the study to provide a "trail" for evaluating the student's learning strategies. An example of such a trail is provided by Figure 4. As shown, trail data identify the type of lesson content selected (RU, EX, or PR), the level of difficulty (e, m, or h), helps accessed (H), the correctness of the response to practice questions (1's represent correct answers), and the latency (seconds) between successive choice responses. Data for each student were summarized to determine the total number of responses, the time required for each lesson, and the test score obtained on the student's first attempt to pass the lesson criterion test.

Analysis

Overall performance data and CBI lesson data were compared using a one-way analysis of variance (ANOVA) procedure. Chi-square data were used to compare choice data.

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325's data; output1 = maps.

More... [illegible]
3 output1's.

Date: 1[illegible]/[illegible]1/7[illegible]

OB	RU	EX	PR	s	r	t
1					-	2[illegible]
1	◆			m	-	39
1		◆		m	-	34
1		◆		m	-	23
1		◆		m	-	2[illegible]
1			◆	m	2	57
1			◆	m	1	29
1			◆	m	1	39
1			◆	m	1	24
2					-	69
2	◆			m	-	9
2		◆		m	-	[illegible]
2		◆		m	-	19
2			◆	m	[illegible]	19
2			◆	m	1	15
3					-	1[illegible]
3	◆			m	-	25
3		◆		m	-	27
3		◆		m	-	14
3		◆		m	-	13
3			◆	m	1	39
3			◆	m	1	27
3			◆	m	1	2[illegible]
3			◆	m	1	[illegible]
3			◆	m	[illegible]	14

Time: 12.47.24
t= 11 min's.

Date: 1[illegible]/[illegible]1/7[illegible]

OB	RU	EX	PR	s	r	t
3			◆	m	1	24
4					-	26
4	◆			m	-	8
4		◆		m	-	25
4		◆		m	-	13
4		◆		m	-	1[illegible]
4			◆	m	1	29
4			◆	m	2	22
4			◆	m	1	33
4			◆	m	1	12
4			◆	m	1	21
4			◆	m	1	17
4			◆	m	1	19
5					-	23
5	◆			m	-	6
5		◆		m	-	19
5		◆		m	-	18
5			◆	m	4	21
5			◆	m	1	13
5			◆	m	1	16
6					-	22
6	◆			m	-	21
6		◆		m	-	20
6		◆		m	-	15
6		◆		m	-	12

Time: 12.55.19
t= 8 min's.

Date: 1[illegible]/[illegible]1/76

OB	RU	EX	PR	s	r	t
6			◆	m	1	3[illegible]
6			◆	m	1	2[illegible]
6			◆	m	1	17
7					-	34
7	◆			m	-	93
7		◆		m	-	4[illegible]
7		◆		m	-	21
7		◆		m	-	26
7		◆		m	-	19
7		◆		m	-	27
7			◆	m	[illegible]	86
7			◆	m	1	51
7			◆	m	1	42
7			◆	m	1	2[illegible]
7			◆	m	1	22
7			◆	m	1	21
7		◆		h	-	44
7		◆		h	-	14
7		◆		h	-	13
7		◆		h	-	9
7		◆		h	-	9
7			◆	h	1	54
7			◆	h	1	2[illegible]
7			◆	h	1	23
7			◆	h	1	27

Time: 13.[illegible]8.33
t= 13 min's.

Figure 4. Typical response sequence (trail) for PC student.

RESULTS

Performance

There were no significant differences in performance on the CBI tests among the experimental groups, and the overall performance of the experimental groups on the hands-on performance and module tests did not differ significantly from that of the control group. Tables 2 and 3 provide group performance on the CBI lesson tests and module tests respectively.

In the Ohms and Voltage Lessons, the Programmed Control (PC) Groups made significantly fewer responses than the Unguided Learner Control (ULC) or the Guided Learner Control (GLC) Groups ($df = 2,121$, $MSW = 9126$, $F = 5.85$, $p < .01$ in the Ohms Lesson, and $df = 2,121$, $MSW = 409$, $F = 13.23$, $p < .001$ in the Voltage Lesson). When the frequency of response data from these two lessons was examined to find the source of this difference, it was found that the number of "easy" level responses accounted for the difference between the groups in the Ohms Lesson, but not in the Voltage Lesson. When the effect of the easy responses was removed, the difference in the total number of responses made by the groups was no longer significant for the Ohms Lesson but was still significant, at the .01 level ($MSW = 710$, $F = 5.07$), for the Voltage Lesson. As is shown in Table 2, there was no significant savings in time required for the PC group, in spite of members making fewer responses in these two lessons.

Individual measures, as reflected in scores taken from tests administered prior to selection to the BE/E School, are provided in Table 1. No evidence of correlation was found between these individual measures and the overall performance measures.

Subject Matter Area Selection

As indicated previously, the ULC and GLC groups had complete freedom of choice in selecting the subject matter area from a lesson index. An analysis was made to determine the percentage of students in each group who selected subject matter areas in numerical sequence. The results are provided in Table 4, which shows that the differences between the two groups were significant in three of the four lessons, $df = 1$, and $\chi^2 = 7.06$, $p < .01$ in the Ohms Lesson, $\chi^2 = .89$, $p > .50$ in the Amps Lesson, $\chi^2 = 4.99$, $p < .05$ in the Voltage Lesson, and $\chi^2 = 7.25$, $p < .01$ in the Volts Lesson. The GLC Group also chose lesson segments in order less frequently than was required of the PC Group (100%) in the Ohms, Amps, and Volts Lessons ($df = 1$, $\chi^2 = 16$, $p < .001$ in the Ohms Lesson, $\chi^2 = 14$, $p < .001$ in the Amps Lesson, and $\chi^2 = 5.70$, $p < .05$ in the Volts Lesson). There was no significant difference in lesson performance between students who did access the subject matter areas in numerical sequence and those who did not.

Table 2

Performance of CBI Groups

Lesson/Group	Test Score (%)	Number of Responses	Study Time (Hours)
Ohms Lesson			
Unguided Learner Control	80.1	216	2:05
Guided Learner Control	81.0	231	2:14
Programmed Control	84.6	163*	1:49
Amps Lesson			
Unguided Learner Control	72.3	249	1:57
Guided Learner Control	66.1	243	1:59
Programmed Control	73.0	204	1:46
Voltage Lesson			
Unguided Learner Control	93.6	68	0:26
Guided Learner Control	95.1	65	0:26
Programmed Control	95.5	47**	0:22
Volts Lesson			
Unguided Learner Control	85.6	215	1:41
Guided Learner Control	88.8	230	1:52
Programmed Control	87.3	217	1:45

*$p < .01$
**$p < .001$

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Table 3

Module Performance

Group	Module 3		Module 4	
	Trials, Performance Test	Errors, Module Exam	Trials, Performance Test	Errors, Module Exam
Unguided Learner Control (N = 38)	1.1	2.4	1.8	0.8
Guided Learner Control (N = 44)	1.4	2.1	1.8	0.9
Programmed Control (N = 42)	1.3	2.3	1.6	1.0
Control (No CBI) (N = 40)	1.2	1.7	1.7	0.8

Table 4

Frequency With Which Students Selected Subject Matter Areas in Numerical Sequence

Lesson	ULC Students (%)	GLC Students (%)
Ohms	34	66**
Amps	61	73
Voltage	82	98*
Volts	61	85**

*$p < .05$
**$p < .01$

Content Selection

In selecting lesson content, GLC students followed the advisor strategies significantly more often than the ULC students (df = 1, $\chi^2 = 299$, $p < .001$). As shown in Table 5, the primary choice of both groups was the rule-example-practice strategy. Between the Ohms and Amps Lessons there was a significant change in the frequency with which this strategy was used (df = 1, $\chi^2 = 16$, $p < .001$ for the ULC Group, and $\chi^2 = 72$, $p < .001$ for the GLC Group). In the Ohms Lesson, the ULC and GLC Groups selected the rule-example-practice strategy 34 and 57 percent of the time respectively. In the Amps, Voltage, and Volts Lessons, both groups maintained approximately the same use frequency (46 and 70% for the ULC and GLC Groups respectively).

Table 5

Frequency With Which Advisor Strategies Were Used by ULC and GLC Students

Strategy Used	ULC Students (% of time)		GLC Students (% of time)	
Advisor Strategy				
Rule-Example-Practice	42		63	
Example-Rule-Practice	5		18	
Practice Only	10		5	
Practice-Rule-Example	1		1	
Total		58		87*
Other		42		13
GRAND TOTAL		100		100

*$p < .001$

To assess the effect of strategy selection on performance, ULC and GLC students were assigned to a posterior strategy groups based on the dominant strategy used. Examination of the student trails (e.g., Figure 4) revealed that 89 percent (N = 39) of the GLC students had selected a dominant strategy, compared to 61 percent (N = 23) of the ULC students--a difference that is significant at the .01 level (df = 1, χ^2 = 9.60). Of a possible 33 times (i.e., for the 33 subject matter areas in the four lessons), ULC students used their dominant strategy 24 times; and the GLC students, 26 times.

As indicated in Table 6, the dominant strategy used most frequently by both ULC and GLC students was rule-example-practice, an advisor strategy. Other strategies that were dominant for ULC students were example-rule-practice (N = 1), practice only (N = 2), rule-practice (N = 1), and example-practice (N = 2)--the former two of which are advisor strategies. The only strategy other than rule-example-practice that was dominant for GLC students was example-rule-practice (N = 5), an advisor strategy.

For the a posteriori analysis, students were classified depending on whether or not they used rule-example-practice as their dominant strategy. When the performance of individuals within these two classifications was compared for all four lessons, as shown in Table 6, it was found that those in the rule-example-practice group performed significantly better than those in the "other" group in three of the four lessons. The differences were significant at the .01 level: df = 1,80, and MSW = 175.4, F = 8.10 in the Ohms Lesson; MSW = 7.15, F = 80.0 in the Voltage Lesson; and MSW = 29.8, F = 80.0 in the Volts Lesson. The performance of the a posterior rule-example-practice group did not differ from that of the PC group, who used the rule-example-practice strategy in all lesson subject matter areas. Also, there was no apparent difference in individual GCT and ARI measures between ULC and GLC students who used the rule-example-practice strategy and those who used "other" strategies.

Table 6

ULC and GLC Student Performance on Lesson Tests
As a Function of Strategy Selection

Lesson	Dominant Strategy: Rule-Example-Practice (N = 51)	Other (N = 31)
Ohms	83.5	74.9*
Amps	71.2	68.1
Voltage	96.2	91.5*
Volts	88.2	77.1*

*p < .01

Attitude Toward CBI Lessons

Table 7, which provides the results of the questionnaire administered to the three experimental groups, indicates that there is no apparent difference in attitude toward CBI lessons. These results are contrary to what was expected, on the basis of subjective analysis, since ULC students appeared to be more enthusiastic than GLC students, who, in turn, appeared to be more enthusiastic than PC students. Results of exit interviews also failed to support the impression of a difference in attitude.

Table 7

Questionnaire Results

Item	ULC Group (N = 38)	GLC Group (N = 44)	PC Group (N = 42)
Lesson Rating:			
Good	32	38	39
Average	2	—	2
Poor	—	—	—
Content Rating:			
Easy	9	9	10
Average	22	24	24
Hard	—	1	1
Organization Ratings:			
Well Organized	34	37	26
Average	2	2	2
Pooly Organized	—	—	—
1. Logical lesson sequence?	Y-34, N-2	Y-38, N-3	Y-41, N-0
2. Material difficult?	Y-5, N-32	Y-2, N-39	Y-3, N-40
3. Explanations adequate?	Y-34, N-2	Y-36, N-5	Y-41, N-1
4. Rule helpful?	Y-34, N-2	Y-41, N-0	Y-42, N-0
5. Enough graphics?	Y-36, N-2	Y-40, N-1	Y-42, N-0
6. Enough examples?	Y-35, N-2	Y-38, N-3	Y-42, N-0
7. Enough practice?	Y-34, N-3	Y-38, N-2	Y-42, N-0
8. Lessons difficult?	Y-3, N-34	Y-6, N-35	Y-3, N-39
9. Enough time?	Y-35, N-2	Y-41, N-0	Y-42, N-0
10. Adequate tests?	Y-34, N-2	Y-40, N-0	Y-42, N-0
11. Procedures troublesome?	Y-5, N-32	Y-9, N-32	Y-6, N-36
12. CBI preference (mean %)	75	78	79
13. Comments:	Generally favorable	Generally favorable	Generally favorable

Note. All items abbreviated for report presentation.

DISCUSSION

It was anticipated that providing guidance would help to optimize the learning process by reducing the number of irrelevant responses made and the time required to complete the instructional sequences. However, the performance data (Table 2) do not support this expeetation. Further, data provided by the questionnaire cast doubt on the subjective observation that the Unguided Learner Control (ULC) students were more enthusiastic about their training than the Guided Learner Control (GLC) and Programmed Control (PC) students.

It should be noted that the advisor subroutine provided for GLC students was "on" most of the time, the only exceptions being when the student was (1) selecting the initial type of lesson content (rule, example, or practice) to be seen within a subject area, or (2) executing practice problems. Thus, by the time the GLC students had finished all four lessons, they seemed to be pretty much under the influence of the advisor, having selected subject matter areas in numerical sequence 80 percent of the time; and advisor strategies, 87 percent of the time—compared to 59 and 58 percent respectively for ULC students. In spite of these strategy differences, the performance of the two groups did not differ.

The performance of the ULC and GLC students who settled on a dominant rule-example-practice dominant strategy seemed to be significantly better on three of the four lesson tests than that of students who settled on "other" strategies. The exception was in the Amps Lesson, which was the most difficult of the four. Both experimental and control subjects had difficulty with the concepts presented in this lesson, and most of the errors made in the Module 4 tests related to those concepts. Also, the variance in the test scores on this lesson was significantly higher, at the .01 level, than in the other three. Because of the small number of students adopting other dominant strategies, it was not practical to make strategy-by-strategy comparisons, to determine whether one strategy was superior to others or whether adopting a dominant strategy is superior to not adopting one. This procedure should be included in future research.

The manner in which students arrived at their dominant strategy is also of interest. An examination of individual student trails showed that 55 percent of the ULC students and 68 percent of the GLC students tended to pick a strategy in the first lesson and then stick with it. An additional 8 and 10 percent of ULC and GLC students respectively adopted a dominant strategy in the second lesson, and then continued to use it in the last two lessons. Only one student—in the ULC group—changed his dominant strategy from that which he had preferred in the first two lessons.

The majority of students who had freedom of choice may have selected the rule-example-practice strategy because of a set established in the introductory computer lesson or because it is a natural selection for most students. As mentioned previously, to ensure that strategy selection would not be influenced by the orientation of the touch panel function block (see Figure 2), the order of presentation of the rule, example, and practice blocks was randomly scrambled for <u>each</u> presentation. This procedure appeared not to be effective (or necessary), as evidenced by the fact that the proportion of ULC students who selected the rule-example-practice strategy in this study (42%) was almost precisely the same as that in a previous experiment (43%) (Lahey & Crawford, 1976).

Although the results of this study do not provide evidence that learner control of lesson strategy is pedagogically advantageous, it appears to be at least as effective as programmed control. Further, the lesson structure facilitates the development, evaluation, and modification of lesson materials. Since the entire branching structure is contained in the driver, changing or relocating an item requires only changes in the affected units or subroutines. This not only saves time, but also eliminates possible sources of error.

A second advantage is that the lesson driver provides a simple way to manipulate one or another control variable, as was done in the present study. Lesson materials can be presented according to a mode selected by the lesson designer, either learner- or program-controlled, or some combination of the two. Such an arrangement may have substantial benefits if it is found that different modes (treatments) interact with different student capabilities (aptitudes), as postulated by Cronbach and Snow (1977).

CONCLUSIONS

This study indicates that learner control of the instructional sequence can be as effective and economical, from a student standpoint, as programmed control. Moreover, if a rule-example-practice lesson strategy is indeed the most effective overall lesson strategy, it would appear that employing this strategy in a programmed control mode would be more effective than letting the student discover and use it on his own.

It appears that, while the learner can be influenced to use an "optimum" strategy by specific guidance, the use of point-to-point guidance may be unnecessary and wasteful of computer space and lesson development time. If any one instructional sequence strategy is indeed superior to others, it may be just as effective to recommend its use during the introduction as to belabor the point during the lesson. Therefore, the use of an advisor (guidance) function as an inherent element of CBI appears to be contraindicated.

The remaining question for research would appear to be whether there is an optimum lesson strategy for the majority of students, and whether it is better to deliver this strategy via learner control or programmed control. The economics of lesson development suggested by Hurlock and Slough (1976), and the benefits postulated by Merrill (1973, 1975), as well as the finding of equivalent performance within this study, indicate that use of learner control of instructional sequence may be optimal for both lesson development and use.

RECOMMENDATIONS

Continuation of this research effort is recommended. As a next logical step in the development of a more complete picture of the utility of learner control of instructional sequence in CBI, it is recommended that the effect of various lesson strategies be investigated experimentally. A rule-example-practice strategy should be compared to other strategies and to the absence of a consistent strategy. In addition, studies should be undertaken to demonstrate the utility of the learner control lesson structure for lesson development by comparing the time required to develop lessons using this mode as opposed to other alternatives. Finally, the usefulness of learner control as a way to teach students how to learn and how to free themselves from dependence on the teacher should be investigated by longitudinal study using this mode of CBI.

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